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1.—THE GEOLOGY AND PHYSIOGRAPHY OF THE JIMPERDING AREA

by

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CONTENTS.

I.—INTRODUCTION. *

The Jimperding Area, situated about 50 miles North-East of Perth by road, is typical of the country forming the Northern parts of the Darling Range. Nearer Perth the areas as previously mapped in detail (Clarke & Williams, 1926 ; Fletcher & Hobson, 1931) consist almost entirely of granitic rocks with later basic intrusions, whereas North of the junction of the Chittering Brook with the Swan River, the country rock changes to ancient metamorphics which appear to be older than the granites forming the Southern parts of the Range.

Attention was first drawn to this area by Mr. J. E. Wells, who, in 1927, noticed the occurrence of andalusite schist in the district. Detailed geological mapping of the area was commenced in 1928, but most of the work was done during 1931 by parties of senior students and the author, working under the leadership of Professor E. de C. Clarke.

The area (which covers approximately 8½ square miles) has been subdivided by the Lands Survey Department, thus obviating the necessity for detailed preliminary survey work. Geological and topographical details were done mainly by chain and compass traverses of the creeks and ridges, while the intervening spaces were filled in by pacing. Levelling, sufficiently accurate for the drawing of form lines, was done by aneroid barometers, using the Jimperding Hill Trig Station as datum. The heights of various points were established by frequent checkings on the Trig station, and intermediate heights were taken from those thus established.

Early in 1931 this locality attracted some attention owing to the discovery of a little alluvial gold in Yinnerding Creek in the Southern part of the area, but a discussion of this occurrence will be deferred to a later part of this paper.

II.—PHYSIOGRAPHY.

A.—General Relief :

Topographically the area can be divided into two sections—(1) a Northern section lying to the North and East of the Jimperding Brook, and consisting of immaturely dissected high land ; (2) a Southern section of maturely dissected country rising gradually to the level of the Darling Peneplain.

The map accompanying this paper clearly indicates that the area is portion of an old tableland. Dissection by Jimperding Brook and its numerous tributaries has produced the present topography.

B.—The Avon River and Its Tributaries :

The Avon River, which flows from East to West along the Northern boundary of the area, is a mature stream flowing in a wide V-shaped valley incised in the old Darling Peneplain. In this area it has two main left bank tributaries—Jimperding Brook and Poison Creek—streams which have several common characteristics, but differ greatly in stage of development. These two streams flow parallel throughout their course, being separated by a ridge of gneissic rock which extends East and West at a general height of 900ft. to 950ft. above sea level.

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MAP and SECTION of POISON CREEK.

0 100 200 300 400

Natural Scale of Feet.

Legend as in Geological Map

Jimperding Brook, which flows in a general Westerly direction throughout the greater part of its course, changes its direction in the centre of the area and flows North, entering the Avon Area near the Northern boundary of the Jimperding area. Jimperding Brook is an intermittent stream which flows rapidly during the winter months, but is reduced to a few disconnected pools during the summer. It is a mature stream flowing over a flood plain about 5 chains wide, in which it has incised a meandering course. The valley is unsymmetrical, the land rising more steeply to the North than to the South, a fact which may be explained by the presence of softer schists to the South and harder and more resistant gneiss to the North.

The tributaries of the Jimperding Brook are small streams which flow only after heavy rains. The general trend is in a Northerly direction, having probably been influenced by major jointing in the rocks. The tributaries are divisible into two main types :—

(a) Those which enter from the Northern side of the Brook, draining the North-Eastern block. These tributaries are mostly short, and all have a steep grade with frequent falls in their course.

(b) Those flowing in from the South and South-West have lower grades, few waterfalls, and are generally of greater length than those of type (a).

The most noticeable feature in the course of Jimperding Brook is the right-angled bend where it changes direction from a Westerly flowing to a Northerly flowing stream. It appears to follow the strike of the rocks which swings round to a Northerly direction in this part of the area. Apart from the fact that the stream is influenced by the strike of the rocks, I have been unable to account for this remarkable change in the course of the stream.

The tributaries, Wonderling Creek, Yinnerding Creek, and Hillsdale Creek, are separated by flattened spurs which show evidence of high level terraces at about 600ft. above sea level.

The North-Eastern section of the area is drained by Poison Creek, a tributary of the Avon River. This stream, which flows parallel to Jimperding Brook, is of juvenile character, having a steep grade with numerous waterfalls in its course. It is intermittent in flow. Although this creek flows only after heavy rains, it is actively degrading its course, and thus differs markedly from the Jimperding Brook, which has nearly reached grade.

The course of Poison Creek appears to have been determined mainly by faulting, and the contrast with Jimperding Brook may be due mainly to this, and to the fact that the Brook flows through a region of softer rocks.

III.—GEOLOGY AND PETROLOGY.

A.—Structural Geology and Field Relations of the Rocks :

1. *The Rocks.*—The rocks exposed in the area under discussion are a series of metamorphics with later acid and basic igneous intrusives.

The metamorphics are a conformable series of quartzites, gneisses, and schists, which occupy the Northern half of the area. They strike West with a general Southerly dip seldom exceeding 20°. A study of the geological map shows that the various types of metamorphic rocks preserve an almost uniform thickness throughout the area. In the Southern part the country is granite with small isolated patches of mica schist. Although the actual contact of the granite and metamorphics has not been found, the boundary is accurate within a chain or so, and clearly shows that the granite is an intrusive mass, and that the isolated patches are roof pendants.

The metamorphics and the granite have both been invaded by acid and basic dykes. The basic dykes have a general North to North-West trend. Some may be followed for a mile or so along their strikes, others can only be traced for a few chains. The basic dykes appear to be more numerous in the South-Western section, where they mostly have a uniform width of two or three chains. The field relations of the basic dykes suggest that they all belong to the one period of instrusion, for no intersecting dykes were found.

The quartz veins and acid dykes (pegmatite and muscovite-garnet-granite bars) have no uniform trend or size, and are usually traceable for short distances only. They appear, however, to be more numerous in the metamorphics situated close to the granite contact than in those farther North.

Later superficial deposits take the form of duricrust and alluvium. The duricrust is developed in the South-Western part of the area, mainly overlying the granitic rocks, but also occurs as residual knolls overlying the metamorphics in the North-Eastern section. Alluvium occurs on the flood plains of the Jimperding Brook and the Avon River.

2. *The Structure.*—The structure consists essentially of a series of conformable bands of crystalline schists, which have been tilted and gently folded. Earth movements have produced tilting mainly towards the South, with minor puckered folds distributed throughout the area. Where Jimperding Brook changes its direction from Westwards to Northwards, there is a distinct variation from the normal strike, and there is a small structural basin where the strike swings round towards the North, which probably accounts for the change in the course of the stream.

The folding in all parts of the area is of a gentle nature, and there has been little faulting in the main body of the metamorphics. In the Poison Creek section in the North-Eastern corner, fault breccia outcrops along the course of the creek, and the existence of a fault is corroborated by mapping. The fault strikes Westward with several branch faults, but owing to the presence of a thick mantle of quartzite rubble, no information regarding the dip or throw can be obtained.

In the Southern part of the area the granite appears to take the form of a bathylithic intrusion as evidenced by the irregular character of the outcrop, and the presence of inliers of mica schist belonging to the metamorphic series. The granite probably extends under the metamorphics, and may be represented by the granite outcrops found several miles to the North-West of the area, but no geological work has been done in this region.

The schists at the head of Beryl Creek and Yinnerding Creek, near the granite contact, are closely folded in a small way. The contortion and puckering seen here are distinct in character from the larger folds in the competent quartzite and gneiss bands farther North. These minor folds appear to result from the action of compressive forces in the incompetent mica schists and quartz mica schists near the granite contact.

B.—METAMORPHIC ROCKS :

The name "Jimperding Series" has been suggested (Clarke, 1930, p. 12) for the metamorphic rocks exposed in this area. They consist of interbedded quartzites, gneisses, basic schists, micaceous schists, and andalusite schists, attaining a total thickness of about 3,500ft., as exposed in the mapped area.

The succession and approximate thickness of the series is as follows, in descending order :—

Micaceous Schist—	A. Ferruginous muscovite Schist ...		250 feet at least.
	B. Andalusite Schist		
	C. Intercalated bands and lenses of Quartzite		
Basic Schist and Gneiss—	A. Tremolite Schist		300–350 feet.
	B. Actinolite Gneiss		
No. 5 Quartzite	... ...		500 feet.
Upper Gneiss ...	... ...		1,800–1,900 feet.
No. 4 Quartzite	... ...		100 feet.
Basic Gneiss ...	... ...		75 ,,
Middle Gneiss ...	... ...		60 ,,
Hornblende Gneiss	... ...		10 ,,
Lower Gneiss ...	... ...		20 ,,
No. 3 Quartzite	... ...		150 ,,
Hornblende Gneiss	... ...		20 ,,
No. 2 Quartzite	... ...		100 ,,
Lower Mica Schist	... ...		20 ,,
No. 1 Quartzite	... ...		Thickness unknown.

The belt of metamorphics probably extends to the West into the valley of Chittering Brook, where it is represented by gneisses, and by kyanite schists, sillimanite schists, and staurolite schists. The Chittering metamorphics appear to have a Northerly strike, to be more steeply dipping, and to be much less regularly arranged than the Jimperding metamorphics. To the North-East the metamorphics are said to occur at Toodyay and Bolgart, with a further occurrence between Northam and Goomalling (Maitland, 1899, p. 28). From Jimperding they also extend South-East to Clackline, and probably farther towards York (Clarke, 1930, p. 13).

1. *Quartzites :*

Several very siliceous bands occur interbedded with the gneisses and schists. These rocks which have a bedded appearance in the field (Fig. 1) and banded appearance in hand specimen, have been termed quartzites. The definition of a quartzite (Hatch and Rastall, p. 298) as " a recrystallised

Fig. 1. Showing bedded appearance and mode of weathering of quartzite.

sandstone in which the original structures are destroyed, and the whole is converted to a mosaic of clear formless crystals of quartz without regular outline, but with closely interlocking crenulated edges " appears to be applicable in the present instance.

In the field, the various quartzites all weather into a flaggy rubble. In any of the quartzites one can generally find greenish mica flakes on the rock cleavage planes. This mica contains chromium and is therefore referred to fuchsite. Thus, the various members of the quartzites are indistinguishable in hand specimen. A marked difference, however, is noticeable in thin section. All have been totally re-crystallised, as evidenced by the complete absence of clastic and cataclastic structures such as interstitial cementing material, granulation, and strain shadows. The texture in all types is granoblastic allotriomorphic with a tendency to granoblastic gneissic in the lower bands.

The characteristics of the various bands are :—

No. 1 *Quartzite.*—Coarse grained, average grain size 1·8 mm. to 2·0 mm., consisting mainly of quartz with subordinate mica and felspar. The mica is developed in colourless flakes and slightly greenish laths about 0·4 mm. long, which frequently penetrate, but are never wholly in the quartz. The mica laths are frequently corroded and contain a yellow stain.

Felspar is clouded, allotriomorphic to subhedral, and is oligoclase.

No. 2 *Quartzite.*—The quartz grains averaging 1·5 mm. to 2·0 mm. in size contain as inclusions numerous small colourless mica rods about 0·015 mm. in length, which have their long axes more or less parallel. Greenish mica (fuchsite) is frequently moulded around the quartz grains. Felspar is rare, but where it does occur it is included in the quartz.

No. 3 *Quartzite.*—The most noticeable characteristic of this band is the grain size. The rock consists of bands of medium-grained granitic texture of average grain size about 0·8 mm. alternating with finer grained bands of gneissic texture of average grain size about 0·3 mm. The fine grained bands contain abundant felspar in irregular elongated allotriomorphs. In this type the felspar is not included in the quartz, and consists of two varieties, viz., microcline predominant, and a plagioclase which has not been indentified.

Apatite and rutile are found as accessories, but both are rare.

No. 4 *Quartzite.*—This type is more equigranular than the No. 3 band. It contains abundant free felspar (mostly microcline) occurring in subhedral to slightly rounded forms. Mica is an important mineral, and occurs in irregular colourless flakes frequently moulded on the felspar.

Apatite and zircon occur as accessories, but both are very rare.

No. 5 *Quartzite.*—The grain size and structures are very similar to those of the No. 4 band, except that felspar is very rare. The chief characteristic of this band is the presence of numerous minute rods of colourless mica, which occur included in the quartz. These inclusions are oriented in a parallel manner with striking uniformity (Fig. 2).

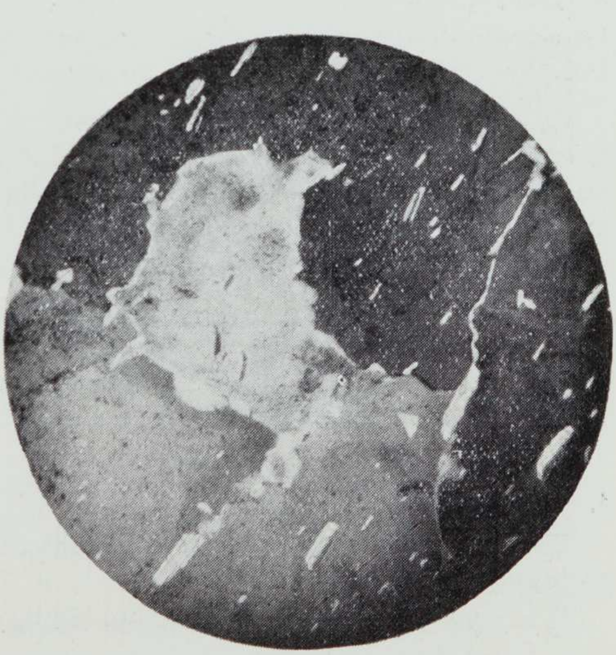

Fig. 2. Photo micrograph. No. 5 Quartzite showing micaceous inclusions in quartz. Crossed nicols x 40.

Photo. H. Smith.

This characteristic, and the fact that felspar does not occur except rarely as inclusions in this type, provide means for distinguishing quartzites of this band from the lower quartzitic members of the series.

2. *Acid Gneisses :*

The acid gneisses are represented by the Upper Gneiss, the Middle Gneiss, and the Lower Gneiss. The main band (the Upper Gneiss) attains a thickness of 1,800ft. to 1,900ft., and in this band numerous basic schlieren, consisting entirely of hornblende, are frequently present in the vicinity of basic dykes. The Middle and Lower Gneisses, which are more basic in composition than the Upper Gneiss, are separated from each other by a band of hornblende gneiss. A band of basic gneiss separates the Middle Gneiss from the No. 4 Quartzite. The total thickness of the four bands does not exceed 170ft.

The texture of all the acid gneisses is holocrystalline gneissic of variable grain. In thin section all the gneisses are granoblastic gneissic to porphyroblastic gneissic. All types have been extensively re-crystallised, as evidenced by the general absence of strain effects, and by the rather even grain in individual specimens. The chief mineral components are quartz, microcline, and plagioclase (all abundant) ; biotite (mostly chloritised) is abundant in some specimens. The accessories are apatite, epidote, iron ore, zircon, and rutile, the last two minerals occurring in a few sections only. Myrmekite is developed in most of the gneisses where plagioclase is in close proximity to microcline.

3. *Basic Schists and Hornblende Gneisses :*

The rocks of this group include hornblende gneisses, basic gneiss, actinolite gneiss, and tremolite schist. Bands of these rocks occur interbedded with the quartzites, schists, and acid gneisses.

The hornblende gneisses occurring near the bottom of the series are exposed in the North-Eastern section of the area. They consist of common blue-green hornblende, quartz, felspar (mainly labradorite), and accessory iron ores (frequently surrounded by a thin rim of sphene), epidote, and apatite.

The band of basic gneiss between the Middle Gneiss and the No. 4 Quartzite is composed of a fine-grained mosaic of quartz, saussuritised felspar, and hornblende, the hornblende being slightly elongated in the direction of gneissosity.

The actinolite gneiss and tremolite schist occur near the top of the series. The actinolite rock is much lighter in colour than the lower hornblende gneisses, and consists of actinolite, quartz, and felspar (mostly albite). The actinolite rock grades up into the overlying tremolite schist, which consists entirely of light green to colourless rod-like aggregates of tremolite.

4. *Mica Schists :*

Mica schists form the uppermost band of the Jimperding Series. They consist of two types :—

(a) Ferruginous muscovite schist.

(b) Ferruginous muscovite schists with andalusite.

The ferruginous muscovite schists consist chiefly of muscovite flakes (stained with reddish oxide) and anhedral quartz. The andalusites are developed in the portion of the mica schists that immediately overlies the basic schists and attain an average size of $1\frac{1}{2}$ cm. x 1 cm. x 1 cm. These crystals become apparent on the weathering of the schist. Many of them show the characteristic chiastolite cross.

The andalusite, by retrogressive metamorphism (Knopf, 1931) is in some places altered in whole or part to an aggregate of muscovite flakes.

Another band of mica schist, similar to the ferruginous muscovite schists described above, occurs near the bottom of the Jimperding Series.

C. IGNEOUS INTRUSIVES :

All the igneous rocks of the Jimperding area are intrusive into the metamorphics of the Jimperding Series. They have been sub-divided as follows :—

(1) Granites and associated acid intrusives—
- (a) Normal granite.
- (b) Pegmatite, aplite, and garnet-muscovite-granite.
- (c) Quartz veins.

(2) Basic intrusives—
- (a) Dolerites.
- (b) Epidiorites.

(1) *Granites and Associated Acid Intrusives :*

(a) *Normal Granite.*—The normal granite crops out in the Southern part of the Jimperding area, and also farther to the North-West along the Avon valley. Its relation to the metamorphics suggests that it is definitely intrusive.

The normal granites are al coarse-grained with a tendency to seriate texture, and consist essentially of quartz, microcline (or orthoclase), with chloritised biotite as the ferromagnesian. In all sections examined, epidote and zoisite were abundant, with apatite as the chief accessory. The plagioclase is invariably saussuritised, whereas the microcline is comparatively fresh. Where these two minerals occur close together there is frequently a development of myrmekitic texture (Fig. 3).

Fig. 3. Photomicrograph showing development of vermicular quartz at the contact of zoned plagioclase and microcline. Crossed nicols x 40.

Photo. H. Smith.

Unaltered biotite is a comparatively rare mineral, as it is mostly changed to greenish chlorite associated with epidote. It occurs in sheaf-like aggregates associated with granular epidote, euhedral apatite, and allotriomorphic quartz. Zircon inclusions surrounded by pleochroic haloes are abundant.

Epidote and zoisite are abundant, the latter mineral being typically developed in the plagioclase felspar.

The granite outcropping several miles North-West of the area is very similar in mineral composition and micro-structure to the Southern granite, and probably is part of the same bathylith.

Rock type (9629) is a granitic rock of rather fine grain, which occurs in contact with steeply dipping quartzite in Fault Creek (a small tributary of Poison Creek). In thin section the rock is very similar to the normal granite, with the exception that felspar exhibiting microcline twinning is absent. The felspars are all water clear, and contain numerous perfect muscovite rods which appear to have been re-crystallised. The felspar is all oligoclase. Chloritic biotite is the ferromagnesian as in the normal granite. Epidote is scarce and the main accessory is apatite. The fresh character of the felspars suggests that the rock is of later crystallisation than the normal granite. It may be a fault intrusion, i.e., a granitic dyke that has come in along the fault plane, subsequent or contemporaneous with the fault, but re-crystallised muscovite suggests that the rock is probably re-crystallised gneiss.

(b) *Pegmatite, Aplite, and Garnet-Muscovite-Granite.*—These are later than (a) above, as they intrude both the granite and the metamorphics. This phase appears to have followed closely upon the granitic intrusion, as the pegmatite dykes occur in greatest abundance in the metamorphics near the granite contact. The pegmatite phase may be conveniently sub-divided into :—

(i) Pegmatites proper—having very coarse texture. They occasionally contain such minerals as molybdenite, columbite, and beryl. The pegmatites consist essentially of quartz and alkaline felspar, with extensive development of muscovite in books and flakes up to 1in. diameter. The pegmatites grade into—

(ii) Garnet-muscovite-granites.—These granites have a medium equigranular texture, and consist essentially of quartz, alkaline felspar, plagioclase felspar, and muscovite, with numerous small pink garnets dotted throughout the rock.

The texture in thin section is allotriomorphic granitic, all minerals except muscovite and garnet being allotriomorphic. The felspars are microcline, which occurs in clear plates up to 1·5 mm. diameter, and oligoclase in clouded allotriomorphs averaging 0·6 mm. diameter. A noticeable feature is the absence of the myrmekite common in the normal granites.

Muscovite is abundant in lath-shaped crystals up to 0·8 mm. long. Secondary muscovite in cloudy aggregates is present in the felspars as the result of sericitisation. Biotite is rare in this type and isolated individuals only are to be found.

Garnet is present in all specimens—it occurs euhedral and its average size is approximately 0·8 mm. The garnets contain inclusions of quartz which occurs in small rounded blebs.

Minute zircons are the only other accessory, and have only been noted in one section, where they occur as inclusions surrounded by a pale pleochroic halo, in the muscovite.

(iii) Garnetiferous Aplites.—These are the fine-grained equivalent of the garnet-muscovite-granites. The prevailing texture is fine equigranular granitic. In thin section the texture is fine-grained, allotriomorphic granitic, and the rock consists chiefly of quartz, microcline, and oligoclase, with accessory chloritised biotite and small pink garnets. The quartz occurs in irregular allotriomorphs usually about 0·25 mm. in diameter, forming a mosaic with the microcline. The garnets are small, averaging from 0·2 mm. to 0·3 mm. in size. Members (ii) and (iii) of the pegmatite group differ from each other in the prevailing finer grain, the absence of muscovite and the smaller size of the garnets in the aplites (iii).

The relations of the pegmatite, aplite, and normal granite are shown by Fig. 4, which is a drawing of a specimen collected near the head of Yinnerding Creek, which shows a pegmatite vein in the normal granite.

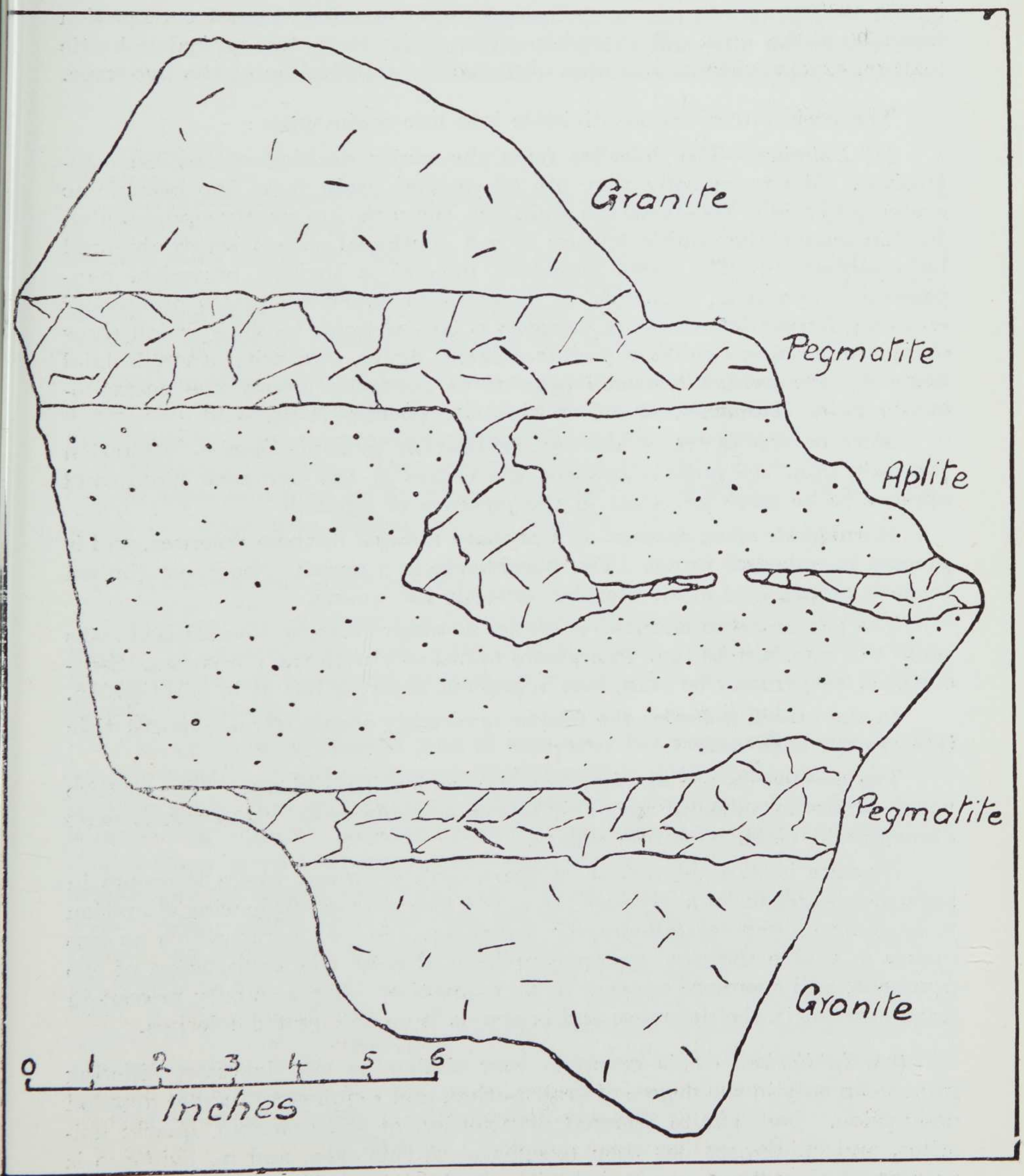

Fig. 4.

(c) *Quartz Veins.*—Quartz veins are of frequent occurrence, one or two are seen clearly cutting across the metamorphics, and it is reasonable to suppose that the frequent occurrence of scattered quartz boulders mark similar veins. As yet, the relation of the quartz veins to the pegmatite phase has not been discovered, but it appears likely that they have followed closely on the pegmatite-aplite dyke phase. Macroscopically the vein quartz is massive granular, consisting entirely of quartz grains. In thin section the vein quartz consists of large interlocking grains up to 5 mms. in diameter, containing innumerable small dust-like inclusions.

2. *Basic Intrusives :*

The basic dyke rocks present in this area represent the latest period of intrusion into the Jimperding Series, and whether they occur in the granite or in the metamorphics, appear to have a uniform mineralogical composition throughout the area. Most of the dyke rocks have the typical doleritic texture, except where it has been obscured by uralitisation of the pyroxene.

The basic intrusives are divisible into two main types :—

(a) *Dolerites.*—The dolerites form the major division of the basic intrusives. Macroscopically they are of variable grain from fine basaltic to coarse gabbroid. Whatever the grain size, the rocks are mostly equigranular. In thin section the ophitic texture is well developed except where obscured by uralitisation. The most abundant mineral is slightly brownish, non-pleochroic pyroxene, occurring in euhedral to subhedral plates ophitically enclosing felspar laths. In convergent polarised light, sections which show oblique extinction exhibit a pseudo-uniaxial figure, indicating a small axial angle for the pyroxene, which appears to approach closely the enstatite-augite series (Thomson, 1911), or pigeonite (Barth, 1931).

Most of the pyroxene shows uralitisation to some degree—alteration proceeds from the outside towards the centre of the pyroxene plates and appears to be more prevalent in the presence of ilmenite.

Hornblende often appears as a primary mineral in these dolerites, and is present in euhedral forms. The hornblende is intensely pleochroic (brown to dark green), and is idiomorphic towards the quartz.

The felspar is labradorite—it occurs as water clear or saussuritised laths up to 0·5 mm. x 0·15 mm. intergrown ophitically with the pyroxenes. Saussuritised felspar may be abundant in sections showing but little uralitisation.

In the quartz dolerites the felspar invariably occurs in micro-pegmatitic intergrowth with quartz.

The accessories are apatite, iron ore, and a little biotite. The apatite which occurs in euhedral rods and prisms showing cross fracturing, is most abundant in types with free quartz.

Ilmenite is most abundant in the quartz dolerites, where it occurs in large grains and skeleton crystals (up to 0·8 mm. diameter) showing alteration to leucoxene along crystallographic directions. In sections in which no free quartz is visible the iron ore appears fresh, despite the uralitisation of the pyroxene, and therefore appears to be magnetite. Pyrite is only present in small amount in the dolerites, and is absent from the quartz dolerites.

(b) *Epidiorites.*—This group is very similar to the dolerites, differing from them only in the degree of uralitisation, and requires no further detailed description. No definite regional distribution of the dolerites, quartz dolerites, and epidiorites has been recognised in this area, and no evidence is present of more than one period of basic dyke intrusion.

D.—LATER ROCKS :

1. *Duricrust :*

The ferro-aluminous duricrust (Woolnough, 1930, p. 125—generally referred to in papers on Western Australian geology as laterite) occurs in the South-Western part of the Jimperding Area, where it has been formed over the normal granite. The duricrust level in this region lies between 850ft. and 950ft. above sea level, being higher by 300ft. in this part of the Darling Range than in areas farther South (Clarke and Williams, 1926). In the North-Eastern block the land rises to the duricrust level in a few places, the duricrust occurring as knolls overlying gneiss or quartzite. The same rock of the Darling Range has been described elsewhere under the name of laterite (Simpson, 1912 ; Clarke, 1919).

In the North-Eastern section of the Jimperding Area the duricrust appears to have formed over the very siliceous quartzites. The first stage in the formation of duricrust over quartzite areas appears to be the coating and staining of the quartz grains with reddish oxide, but no intermediate stages between the iron-stained quartzite and the solid duricrust have been found.

2. *Talus Banks :*

The disintegration of the quartzite gives rise to many talus slopes. North of the Jimperding Brook and East of the head of Boundary Creek, an accumulation of talus about 10ft. thick is being cut through by a small stream. The talus consists of angular fragments of quartzite embedded in a hard clayey matrix, and appears to have accumulated in a basin-shaped hollow. The stream is at present cutting down into the deposit.

To the West of Boundary Creek a definite talus bank occurs as a cliff about 12ft. in height on the side of the hill facing Jimperding Brook. This talus bank is composed of iron-stained angular quartzite fragments embedded in a ferruginous matrix. This occurrence may be explained as an accumulation of talus cemented by limonite, when the river stood at a higher level, which has since been eroded into its cliff-like form.

3. *Alluvium and Alluvial Gold :*

Alluvium occurs along the flood plains of Jimperding Brook and Avon River. It consists of fine soil containing abundant silvery muscovite flakes. In the bed of the brook the material is coarser sand with rounded boulders (mostly quartzite).

The presence of alluvial gold in this area has been noted only in Yinnerding Creek, and although much work has been done in the area, all efforts have failed to find any primary gold-bearing formation.* The gold occurs in small fragments, the angular character and fineness of which suggest either that it has suffered little transportation, probably owing its origin to the pegmatitic and other acid bars which cut through the roof pendant at the head of the creek, or that there has been solution and secondary deposition of the gold in the alluvium. Should the primary gold-bearing formation occur in the schists at the head of Yinnerding Creek, there appears to be little possibility of any considerable lateral extent or persistence in depth for the formation, as geological mapping indicates that these schists form a small roof pendant in the granite, and consequently may not extend to any great depth.

* Since this paper was written I am informed that about 50 tons of ore from quartz leaders in the schist have been crushed for a yield of 15 dwt. per. ton.

IV.—THE ORIGIN OF THE METAMORPHIC ROCKS.

In the absence of chemical analyses of the rocks of this series, field evidence seems likely to give the most useful and reliable criteria for determining the nature of the original rocks.

At this stage it will be convenient to consider each set of rocks, and to summarise briefly the field and microscopical evidence detailed elsewhere, regarding the nature of the original rocks and the processes of metamorphism.

1. *Quartzites :*

A.—*Field Evidence :*

(a) Bedded appearance (Fig. 1).

(b) Persistence in bands of uniform thickness.

(c) Highly siliceous composition.

B.—*Microscopical Evidence :*

(a) General absence of cataclastic structure indicating re-crystallisation.

(b) Presence of oriented mica rods.

The field evidence clearly indicates a sedimentary origin for these rocks, and the microscopical evidence indicates that the rocks were formed under high pressure acting vertically downwards so that the mica flakes crystallised normal to the direction of the impressed force, in a zone where re-crystallisation was the dominant process.

2. *Acid Gneisses :*

A.—*Field Evidence :*

(a) Interbedded with quartzites of supposed sedimentary origin.

(b) Variability of texture and composition across the strike.

(c) Persistence of thickness and outcrop of the upper gneiss.

B.—*Microscopical Evidence :*

(a) Absence of cataclastic structures.

(b) Mineralogical composition similar to that of the normal granite.

(c) Presence of myrmekite.

So far as field evidence goes, the gneisses might have been originally—(1) sediments, (2) granitic sills, or (3) contemporaneous acid flows. The evidence of variation of composition across the strike and of great thickness of the upper gneiss, supports the sedimentary hypothesis rather than the granitic sill theory. The microstructures are indicative of recrystallisation. The mineral association (biotite, epidote, microcline, oligoclase and quartz) is similar to that of the normal granite, but this may be explained by recrystallisation under Grubenmann's mesozone conditions (Leith and Mead, p. 189), where the dominant process is recrystallisation (note absence of cataclastic structure in the gneiss) and remineralisation with the above minerals characteristic.

It appears, however, that very detailed petrological work will be necessary before any definite conclusion is reached regarding the origin of the gneisses. The evidence at present available appears to be slightly in favour of the sedimentary hypothesis.

3. *Basic Schists and Hornblende Gneisses :*

A.—*Field evidence :*

(a) Bedded arrangement.

(b) Presence of andalusite crystals in the mica-schist which immediately overlies the upper basic schists, and decrease in size and abundance of andalusite with increasing vertical height above the basic schists.

B.—*Microscopical evidence :*

(a) Presence of schistose structure and absence of cataclastic effects in the quartz.

(b) Presence of rims of recrystallised sphene surrounding iron ores (in the lower hornblende gneisses).

The field evidence suggests that the basic schists and hornblende gnesises may have been basic sills or flows. The assumption that the upper layer of basic schist was originally a basic sill, is supported by the distribution of andalusite in the overlying schist.

The microscopical evidence indicates that shearing or rock flowage (Leith and Mead, p. 222) was necessary to generate the textures observed. The assumption of shearing having produced the schistose structure is in accord with the quartzite and acid gneiss micro-structures only if this shearing was followed by recrystallisation. The andalusite crystals show no signs of distortion which would be expected under conditions required for the formation of the hornblende gneisses, but this may be explained by the fact that the andalusites are embedded in an incompetent matrix which would probably absorb most of the stress.

The presence of sphene rims around iron ore supports the view that the hornblende schists result from the metamorphism of basic igneous rocks (Teall, 1885), (p. 133).

4. *Mica Schists :*

(a)—*Field evidence :*

Conformable with the quartzites which are regarded as sedimentary.

(b)—*Mineralogical evidence :*

Presence of andalusite.

These schists are characterised by a high alumina content as evidenced by the presence of andalusite, a typical mineral of meta-sediments.

5. *Conclusion :*

Considered generally, the available evidence favours the hypothesis that the Jimperding Series is a series of meta-sediments with intercalated meta-igneous rocks, represented by basic schists and hornblende gneisses. The original nature of the gneissic bands is very doubtful. In the process of metamorphism in the Jimperding Area the earlier forces appear to have been dominantly of directed character, producing schistose structure of the hornblende gneisses and granulation in the quartzites. With later change to lower zone (probably mesozone) temperature-pressure conditions, the forces appear to have been mainly hydrostatic, promoting recrystallisation and production of granoblastic allotriomorphic to granoblastic gneissic micro-structures.

V.—GEOLOGICAL HISTORY OF THE AREA.

The greater part of the area which has been mapped in the Jimperding Valley consists of a series of meta-sediments which have been intruded by later acid and basic intrusives.

The metamorphics consisting of a conformable series of quartzites, gneisses and schists which were probably represented originally by sandstones, grits and mudstones are definitely older that the Darling Range granite, and were probably laid down in early Pre-Cambrian times (probably Yilgarn) (Maitland, 1919). These sediments contained intercalated basic flows and were invaded by basic sills. They were deeply buried, and finally intruded by igneous rocks. The main intrusion was the Darling Range granite bathylith, which was probably instrumental in effecting the greater part of the metamorphism, followed by intrusion of acid dykes, which appeared to follow closely on the granitic intrusion.

The last phase of igneous activity is represented by the basic dyke rocks which intruded all the pre-existing rocks.

The area was now subjected to long continued erosion and there is no evidence of accumulation on it of extensive sedimentary series since the deposition of the Yilgarn (?) sediments. Farther to the South-West in the Bullsbrook district, leaf-bearing shales, possibly of Jurassic age, are found overlying gneiss, but they are absent from the Jimperding Area.

The superficial duricrust belongs to a recent period when the greater part of W.A. was reduced to a peneplain (Woolnough, 1918), and, since this time, the area has been dissected by streams as outlined in the physiographic section of this paper.

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